

# Case Study: Monitoring an EOR Project to Document Sequestration Value

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# Case Study: Monitoring an EOR Project to Document Sequestration Value



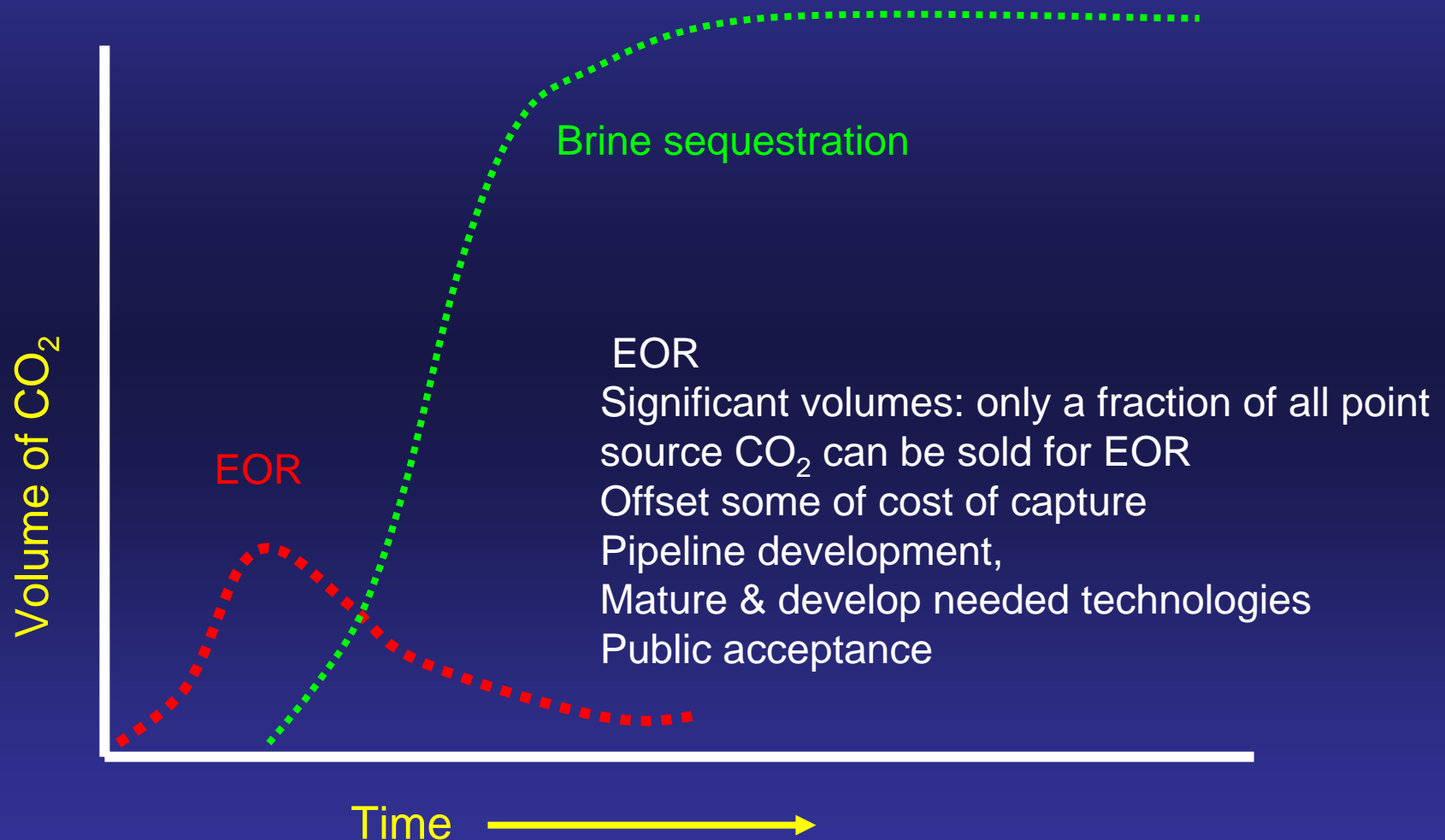
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Bureau of Economic Geology  
Jackson School of Geoscience  
The University of Texas at Austin

# Monitoring Goals For Commercial Sequestration

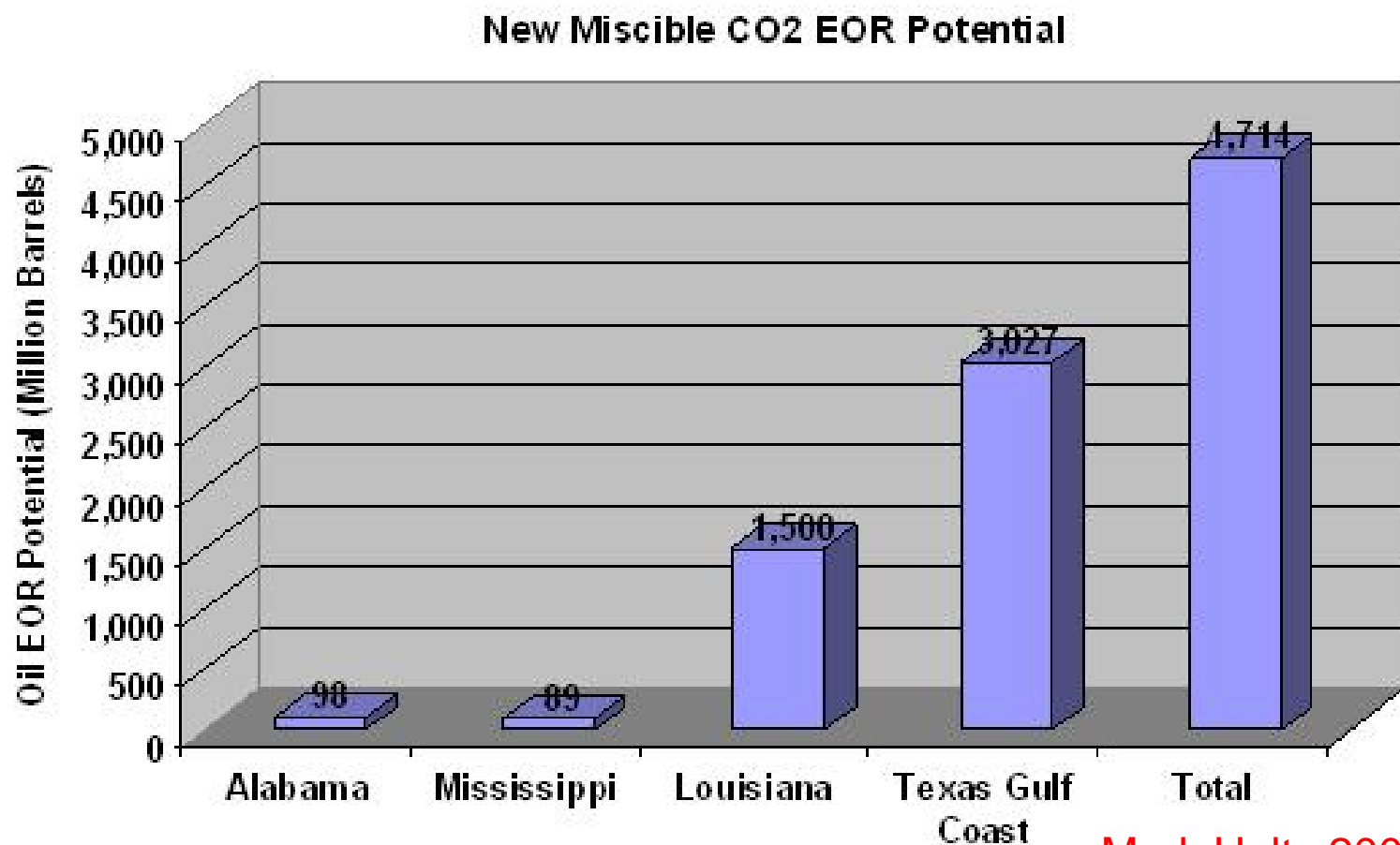
- Storage capacity and injectivity are sufficient for the volume via history match between observed and modeled
- CO<sub>2</sub> will be contained in the target formation not damage drinking water or be released to the atmosphere
- Know aerial extent of the plume; elevated pressure effects compatible with other uses minimal risk to resources, humans, & ecosystem
- Advance warning of hazard allows mitigation if needed
- Public acceptance - provide confidence in safe operation

Modified from J. Litynski, NETL

# Role of EOR in Sequestration



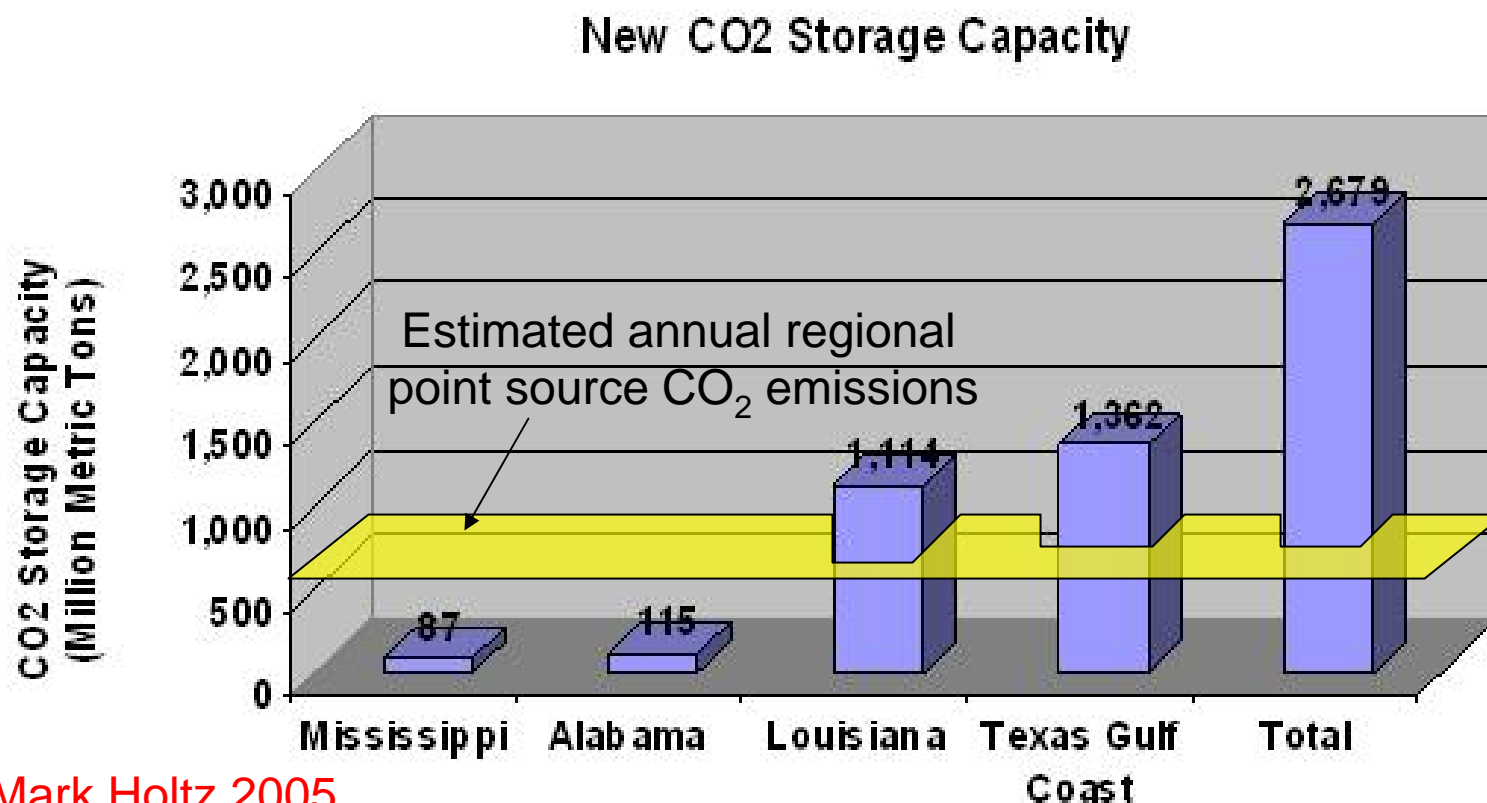
# Miscible CO<sub>2</sub> EOR Resource Potential in the Gulf Coast



Mark Holtz 2005

# CO<sub>2</sub> Sequestration Capacity in Miscible Oil Reservoirs along the Gulf Coast

Bureau of Economic Geology



Mark Holtz 2005

NATCARB Atlas 2007

# How does EOR compare to brine sequestration?

## EOR

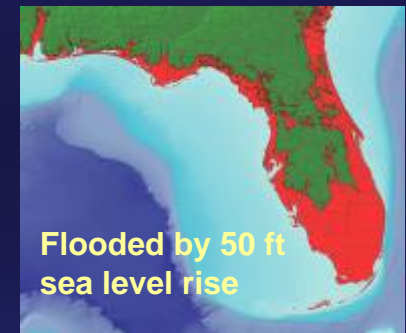
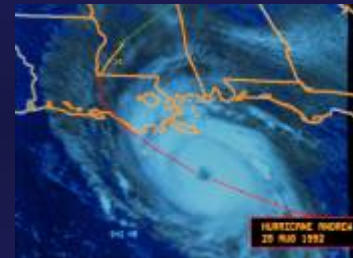
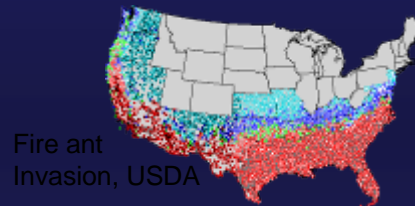
- Recycle with production
- Confined area
  - Trap
  - Pressure control
- Residual oil- CO<sub>2</sub> very soluble
- Many well penetrations =
  - Good subsurface knowledge
  - Some leakage risk

## Brine Reservoir

- Pure storage
- Large area
  - May not use a trap
  - Pressure area increase
- Brine – CO<sub>2</sub> weakly soluble
- Few well penetrations =
  - Limited subsurface knowledge
  - Lower leakage risk

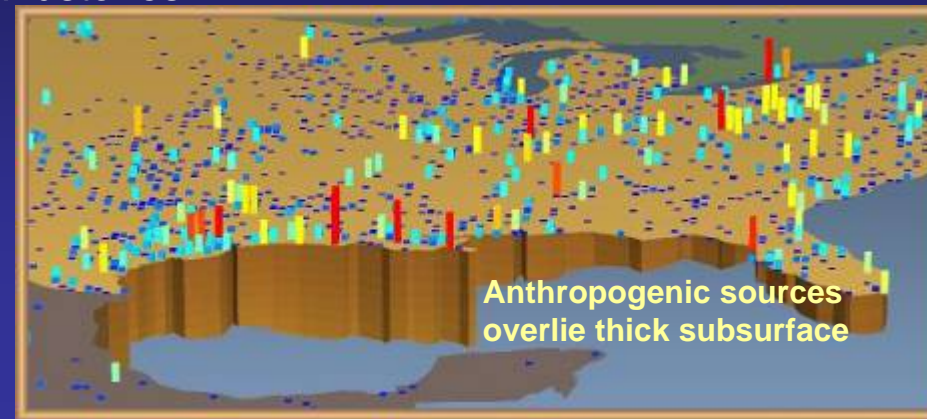
# Southeast Regional Carbon Sequestration Partnership - SECARB

- Southeast US - climate change vulnerabilities
  - Hurricane landfalls
  - Tropical species invasion
  - Low relief coastline – sea level rise inundation



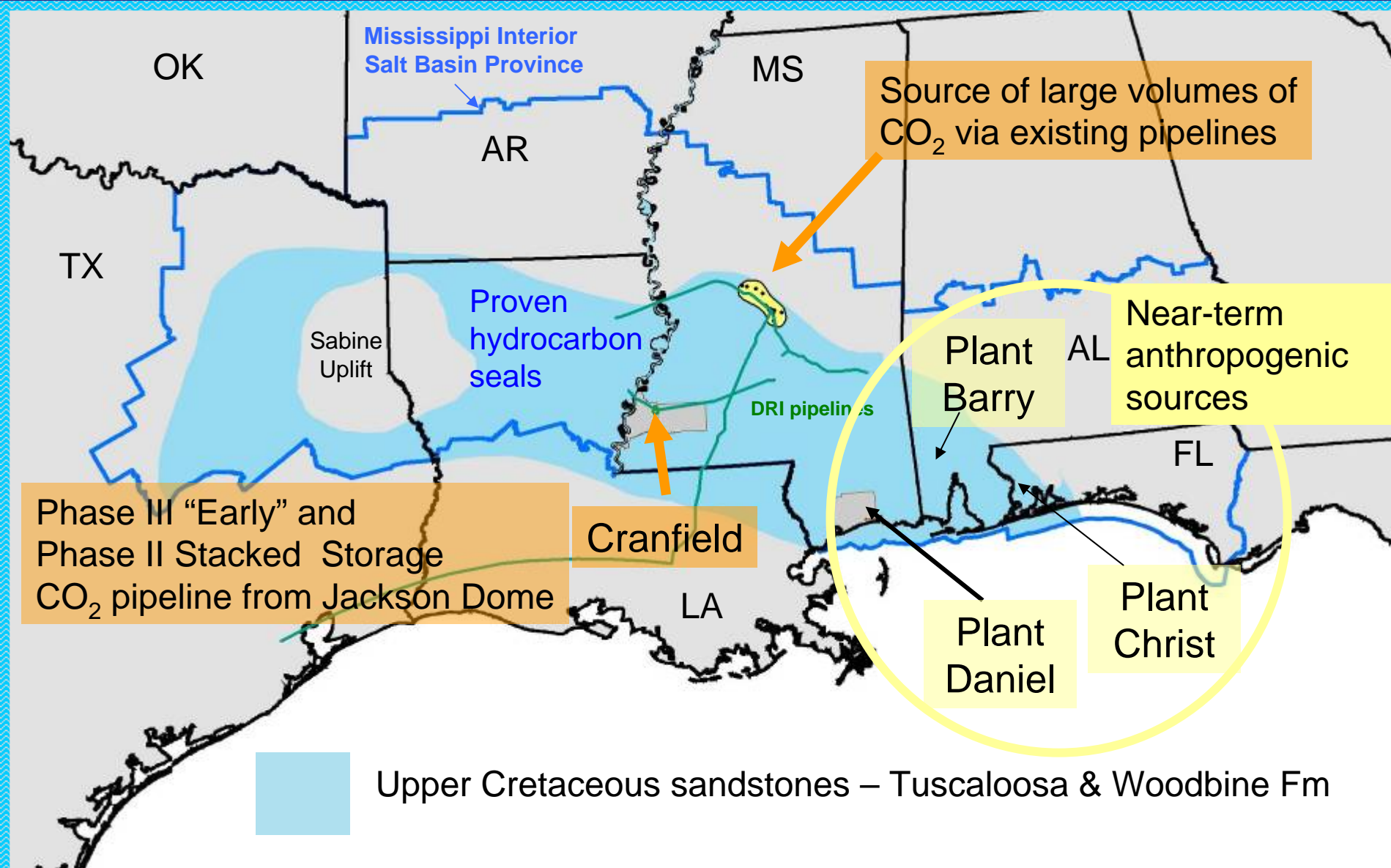
- Southeast US - unique storage potential
  - Energy industry center (refinery and oil production)
  - Very well known,
    - thick wedge -high permeability sandstones
    - excellent seals
  - Initiated by CO<sub>2</sub> EOR

SECARB lead by  
Southern States Energy Board  
Funded by US DOE - NETL



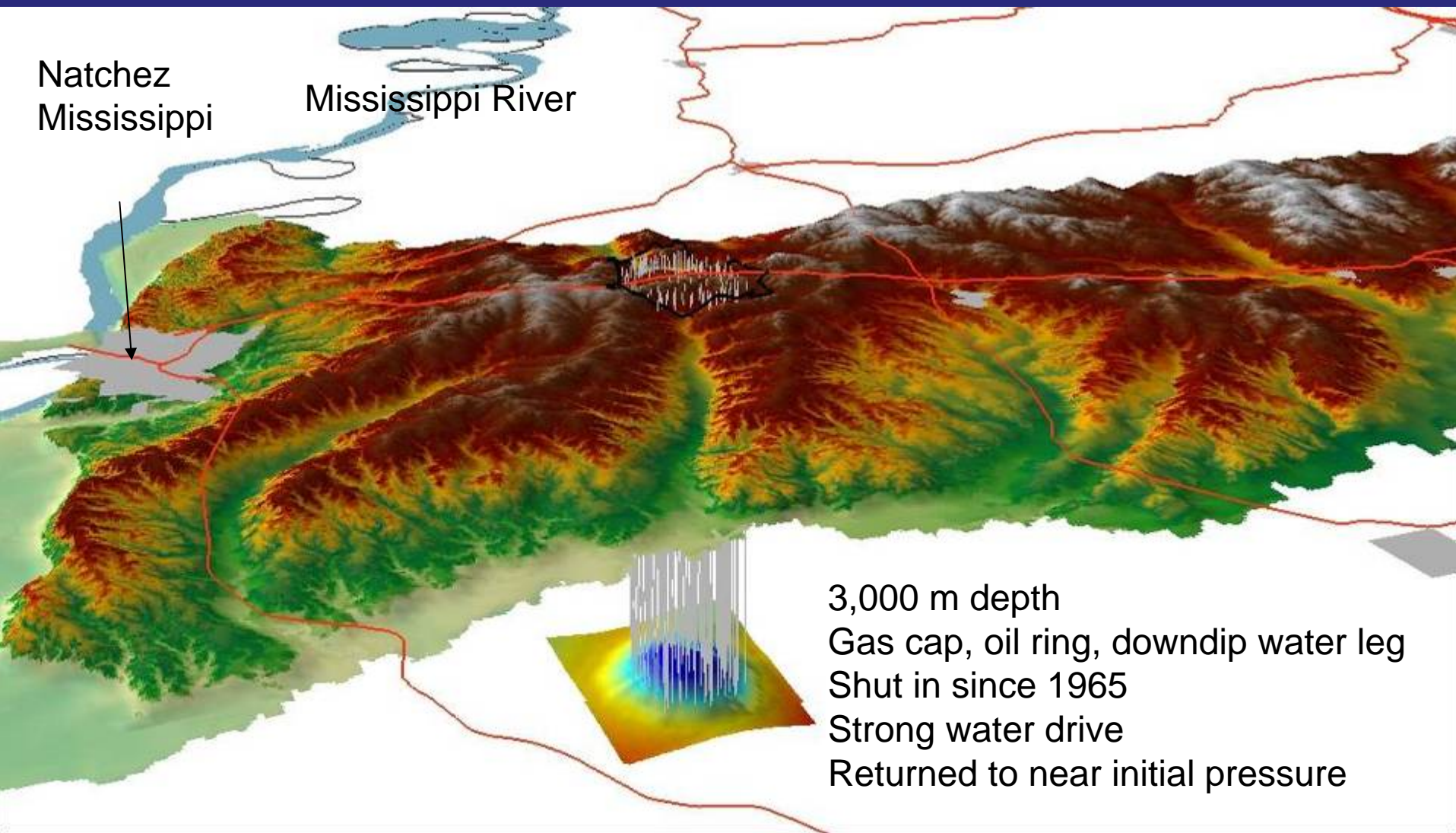


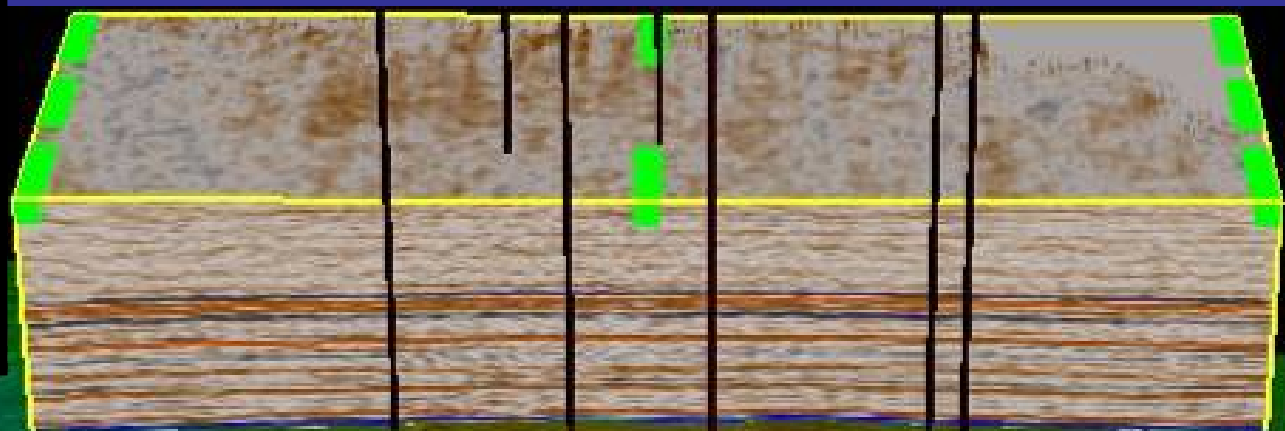
# Sites for NETL-SECARB Phase II and III Linked to near-term CO<sub>2</sub> sources



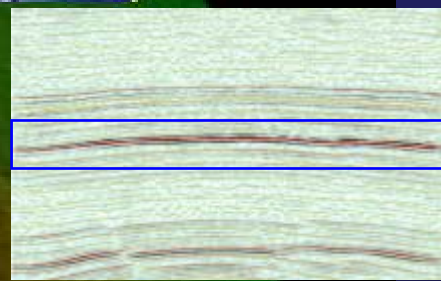
# SECARB Phase III – “Early” test

## Cranfield unit operated by Denbury Resources International





W-E

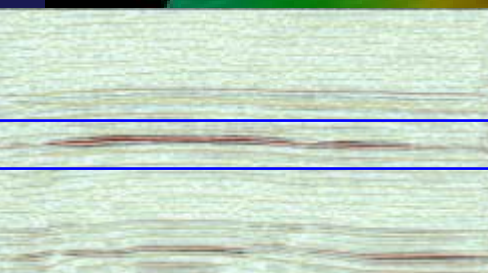


29-12

OBS

S-N

Cranfield Anticline

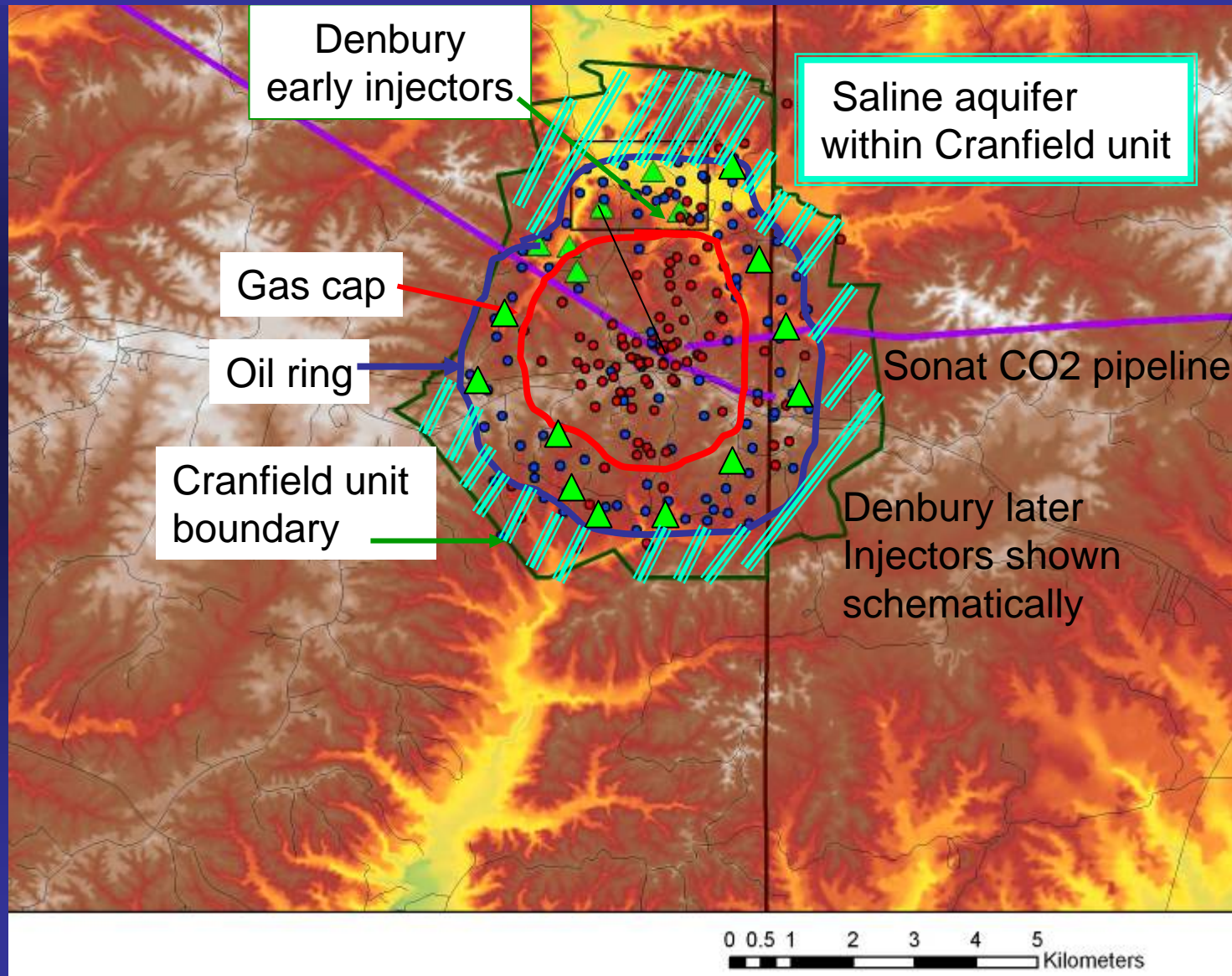


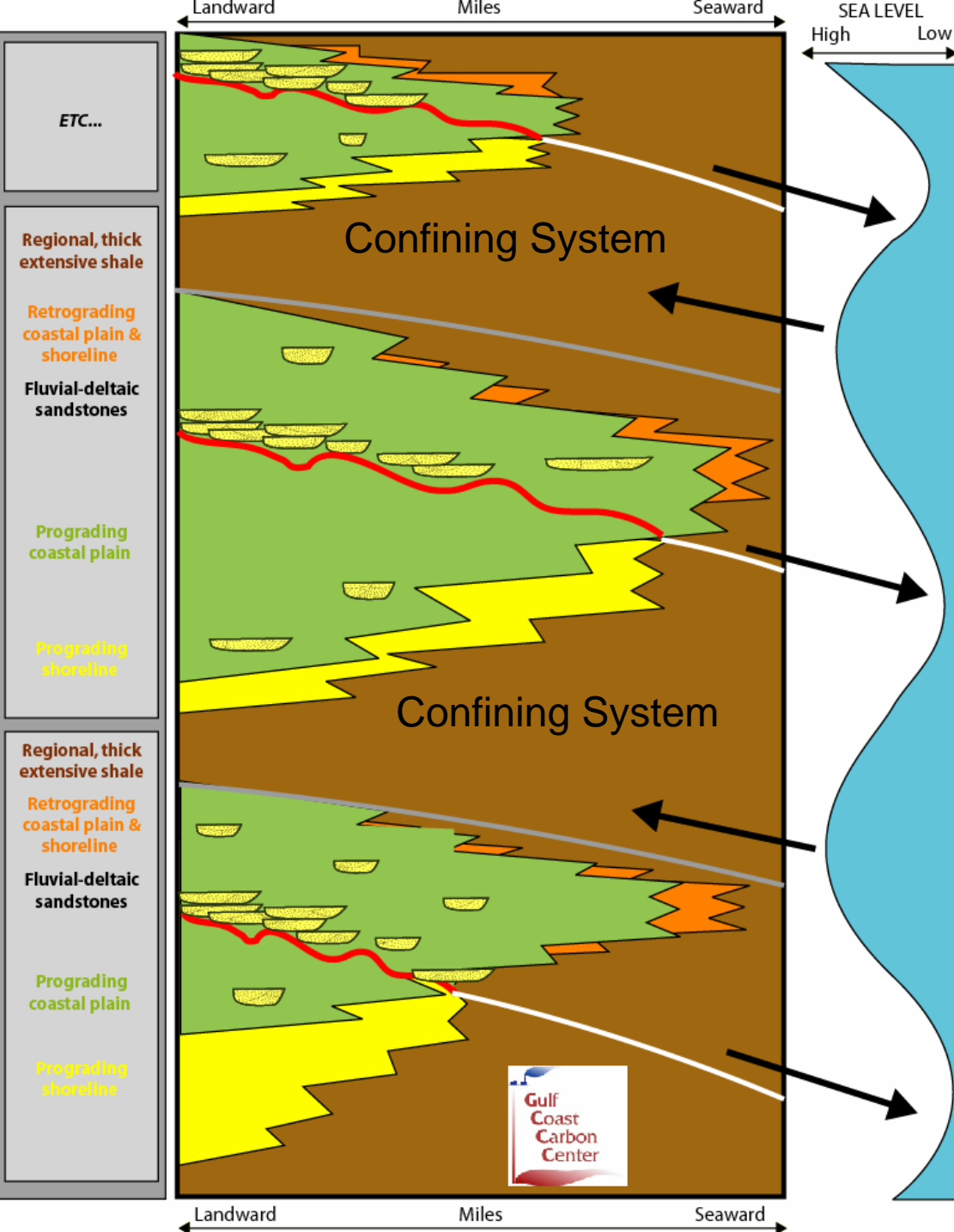
~ 1 mile



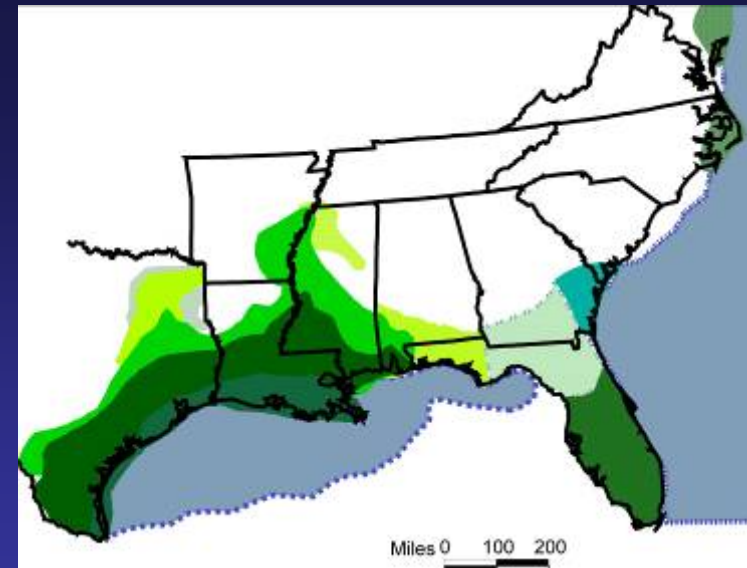


# Cranfield Unit Setting





Repetitive depositional units in the Gulf Coast wedge mean that results from study of one can be easily transferred to both older and younger units and to other parts of the region.





Sweep efficiency brine system – how effectively are pore volumes contacted by CO<sub>2</sub> ?

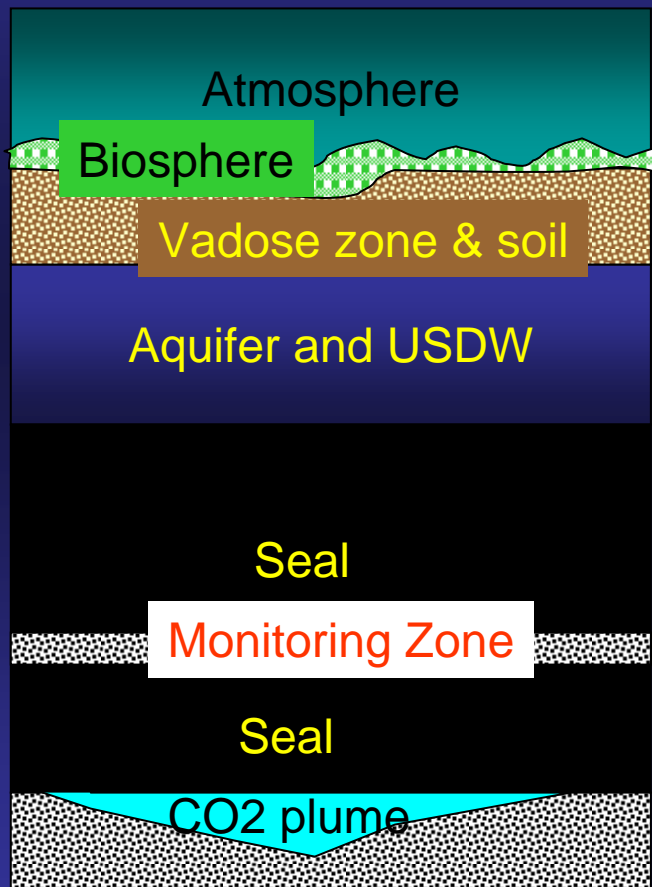
# GEM model – Fred Wang

# Techniques Currently Used to Assure Safe Injection of CO<sub>2</sub>

- CO<sub>2</sub> pipelines health and safety procedures - shipping, handling, storing
- Pre-injection characterization and modeling
- Injectate Isolated from Underground Sources of Drinking Water (USDW)
- Maximum allowable surface injection pressure (MASIP)
- Mechanical integrity testing (MIT) of engineered system
- Well completion / plug and abandonment standards
- Reservoir management



# Monitoring Options



- Atmosphere
  - Ultimate receptor but dynamic
- Biosphere
  - Assurance of no damage but dynamic
- Soil and Vadose Zone
  - Integrator but dynamic
- Aquifer and USDW
  - Integrator, slightly isolated from ecological effects
- Above injection monitoring zone
  - First indicator, monitor small signals, stable.
- In injection zone - plume
  - Oil-field type technologies. Will not identify small leaks
- In injection zone - outside plume
  - Assure lateral migration of CO<sub>2</sub> and brine is acceptable



# How Much is Enough?

	Site Characterization	Monitoring	Mitigation/ Corrective Action	Public Participation
<div> <div>↑</div> <div>More</div> </div>	3-D seismic  Test program  Multiple in-zone wells	4-D seismic  Multiple zones multiple tools  Selected tools selected zones	Redundant injection sites/ pipeline system  Response if non-compliance occurs	<div> <div>           Litigation             Public comment &amp; response mechanisms         </div> </div>
<div> <div>↓</div> <div>Less</div> </div>	Regional + injection well	MIT surface pressure injected volumes	Stop injection	Public hearings  Public information
	Texas Class I			

# SECARB Phase II (Cranfield Oil ring)

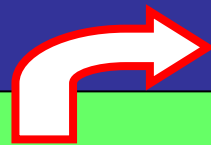
## Overarching Research Focuses

- (1) Sweep efficiency – how effectively are pore volumes contacted by CO<sub>2</sub>?
  - Important in recovery efficiency in EOR
  - Subsurface storage capacity?
  - Plume size prediction
- (2) Injection volume is sum of fluid displacement, dilatancy, dissolution, and rock+fluid compression
  - Tilt to start to understand magnitude of dilatancy
  - Bottom hole pressure mapping to estimate fluid displacement
- (3) Effectiveness of Mississippi well completion regs. in retaining CO<sub>2</sub> in GHG context
  - Above zone monitoring

# SECARB Phase III (Downdip brine leg) Overarching Research Focuses

- Large volume - Multiple wells
- Brine downdip from production
- Follow-on from Phase II issues
  - Tilt, pressure, plume interaction
- Follow-on from Frio test results
  - Direct measurement of plume evolution with CASSM – a “trip wire technology”
  - Dissolution of CO<sub>2</sub> into oil and brine

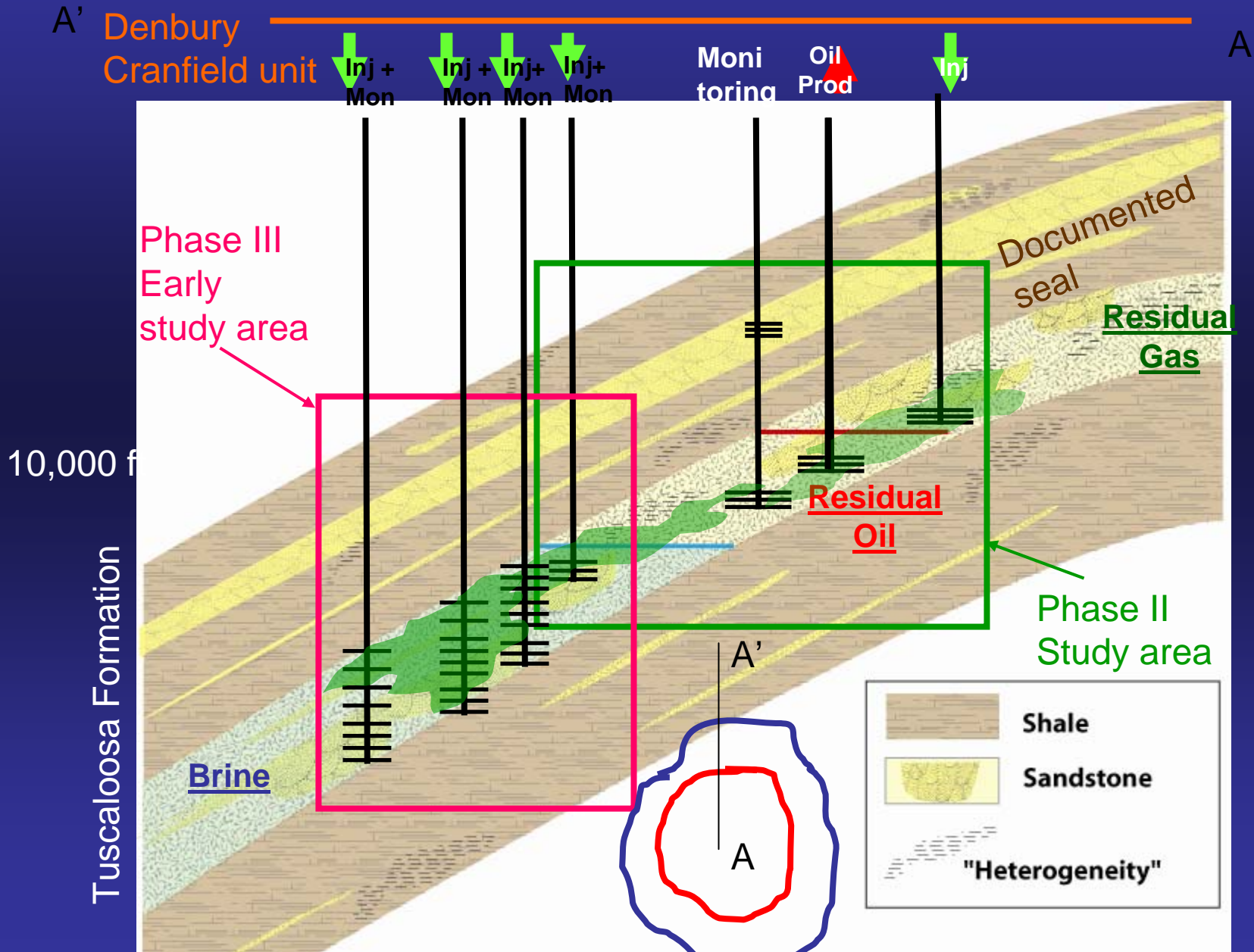
# Integration of Research: Theoretical Approaches Through Commercialization

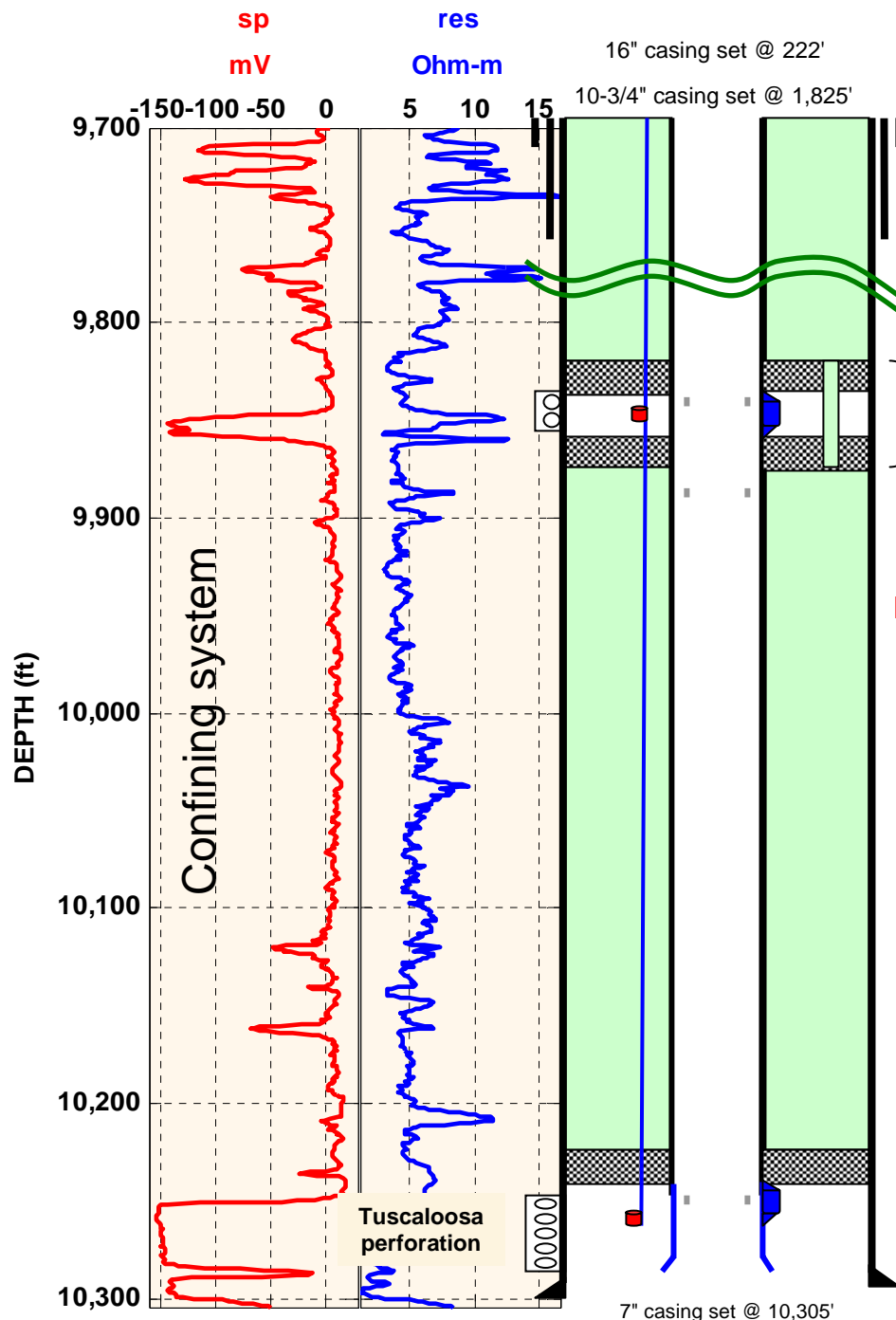


**Commercial Deployment by Southern Co.**

Toward commercialization	Contingency plan Parsimonious public assurance monitoring	Subsurface perturbation predicted	
Hypotheses tested	CO <sub>2</sub> retained in-zone-document no leakage to air-no damage to water	CO <sub>2</sub> saturation correctly predicted by flow modeling	Pressure (flow plus deformation) correctly predicted by model
Field experiments	Surface monitoring: instrument verification Groundwater program CO <sub>2</sub> variation over time  Above-zone acoustic monitoring (CASSM) & pressure monitoring	CO <sub>2</sub> saturation measured through time – acoustic impedance + conductivity Tomography and change through time  3- D time lapse surface/ VSP seismic  Dissolution and saturation measured via tracer breakthrough and chromatography	Tilt, microcosmic, pressure mapping  Acoustic response to pressure change over time
Theory and lab	Sensitivity of tools; saturated-vadose modeling of flux and tracers	Lab-based core response to EM and acoustic under various saturations, tracer behavior	Advanced simulation of reservoir pressure field

# Cranfield Research Overview





Test adequacy of  
Mississippi well  
completions for CO<sub>2</sub>  
sequestration

## Monitoring Zone

13-Chrome Isolation packer w/ feed through  
13-Chrome Selective seat nipple

Pressure transducer Side Pocket Mandrel w/dummy gas valve  
1/4" tubing installed between packers to  
Provide a conduit between isolation packers

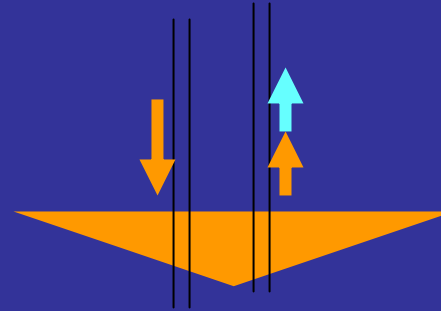
## CO<sub>2</sub> Injection Zone

13-Chrome Production packer w/ feed thru

Pressure transducer Side Pocket Mandrel w/dummy gas valve

# Two areas need monitoring: CO<sub>2</sub> and pressure

In EOR, CO<sub>2</sub> injection is approximately balanced by oil, CO<sub>2</sub>, and brine production no pressure plume beyond the CO<sub>2</sub> injection area

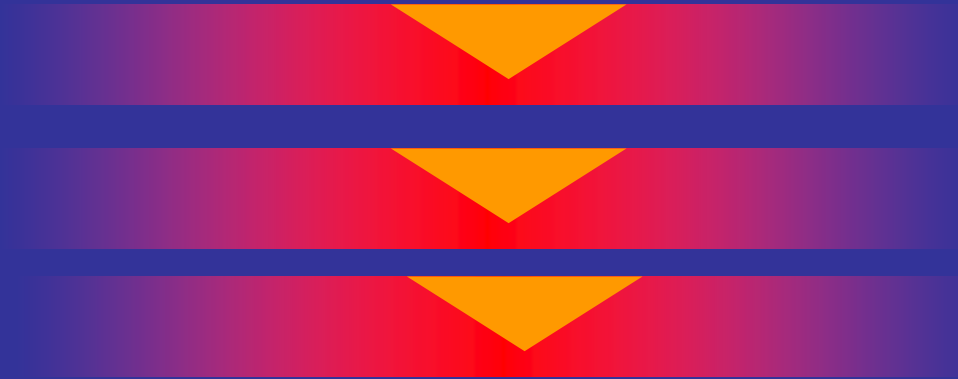


CO<sub>2</sub> injection (no production)  
pressure plume extends  
beyond the CO<sub>2</sub> injection  
area

CO<sub>2</sub> plume

Elevated pressure

# Stacked Storage



- By developing multiple injection zones beneath the EOR zone, the footprint of the CO<sub>2</sub> and pressure plume can be minimized



# Role of Dissolution in Pressure Evolution

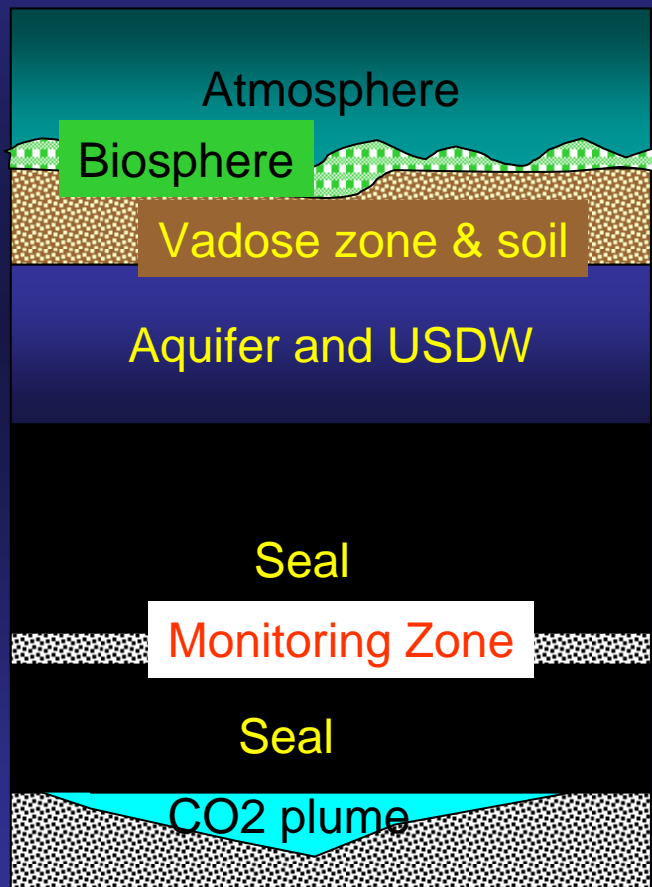
No dissolution: volume displaced =  
Volume injected



Volume displaced =  
Volume injected – volume  
dissolved + fluid expansion



# Surface Monitoring Options

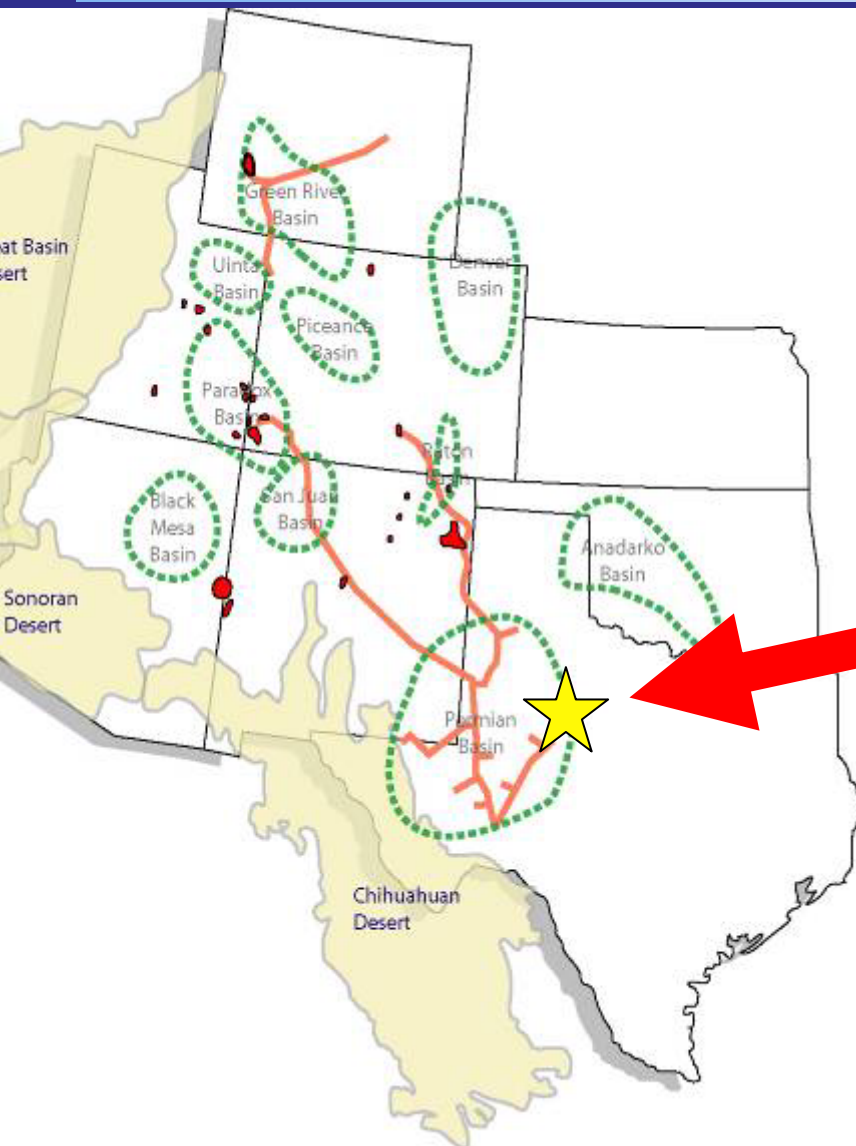


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# Three Surface Monitoring Studies

- Lab studies of effects of CO<sub>2</sub> leakage on freshwater – potential for risk? Potential for monitoring
- Field study at SACROC – any measurable perturbation after 35 years of EOR?
- Cranfield sensitivity analysis? Could leakage be detectable?

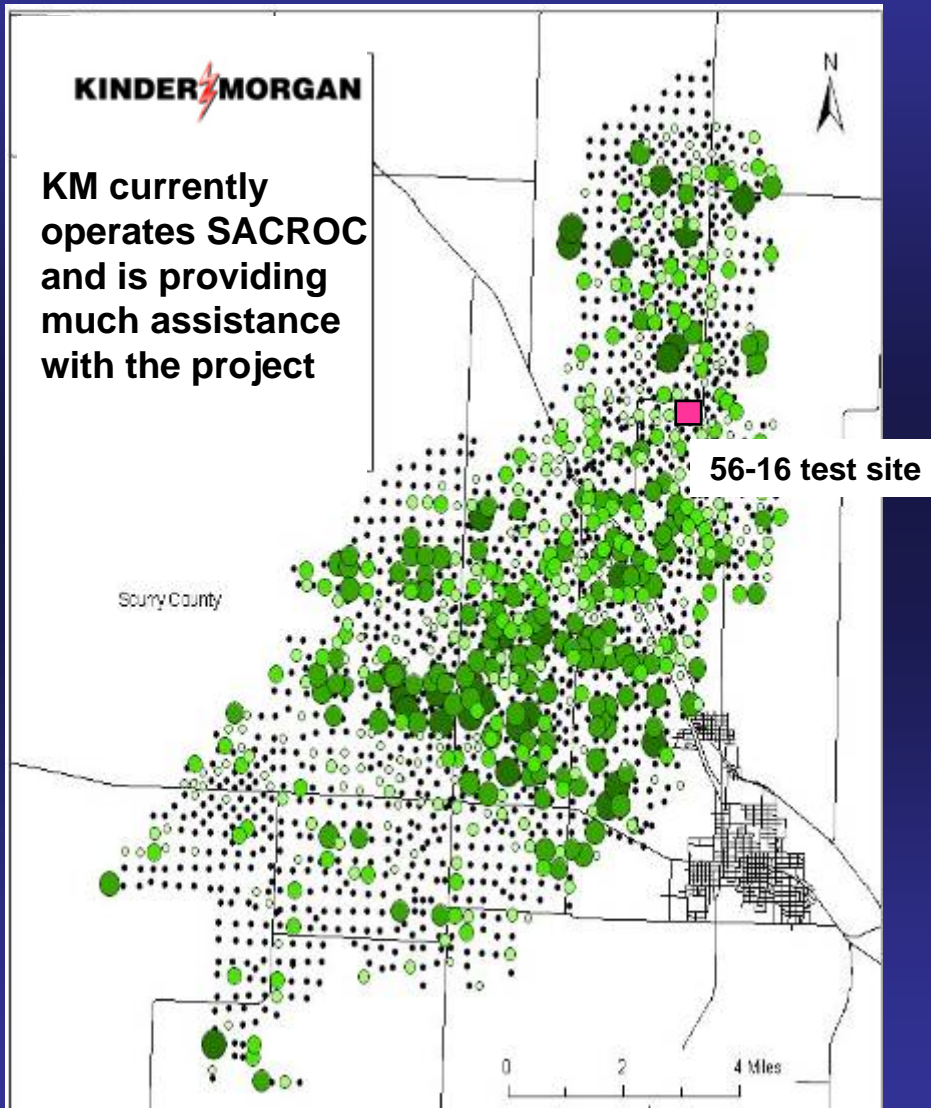
# SACROC – eastern edge Permian Basin



## Scurry Area Canyon Reef Operators Committee (SACROC) unitized oil field

- Ongoing CO<sub>2</sub>-injection since 1972
- Combined enhanced oil recovery (EOR) with CO<sub>2</sub> sequestration
- Depth to Pennsylvanian- Permian reservoir ~6,500 ft

# SACROC Previous CO<sub>2</sub> Injection



- ~140 million tons CO<sub>2</sub> injected for EOR since 1972 for EOR
- ~60 million tons CO<sub>2</sub> recovered
- SWP researchers test if detectable CO<sub>2</sub> has leaked into groundwater

Rebecca Smyth BEG  
Southwest Partnership  
Led by New Mexico Tech / Utah  
DOE / NETL



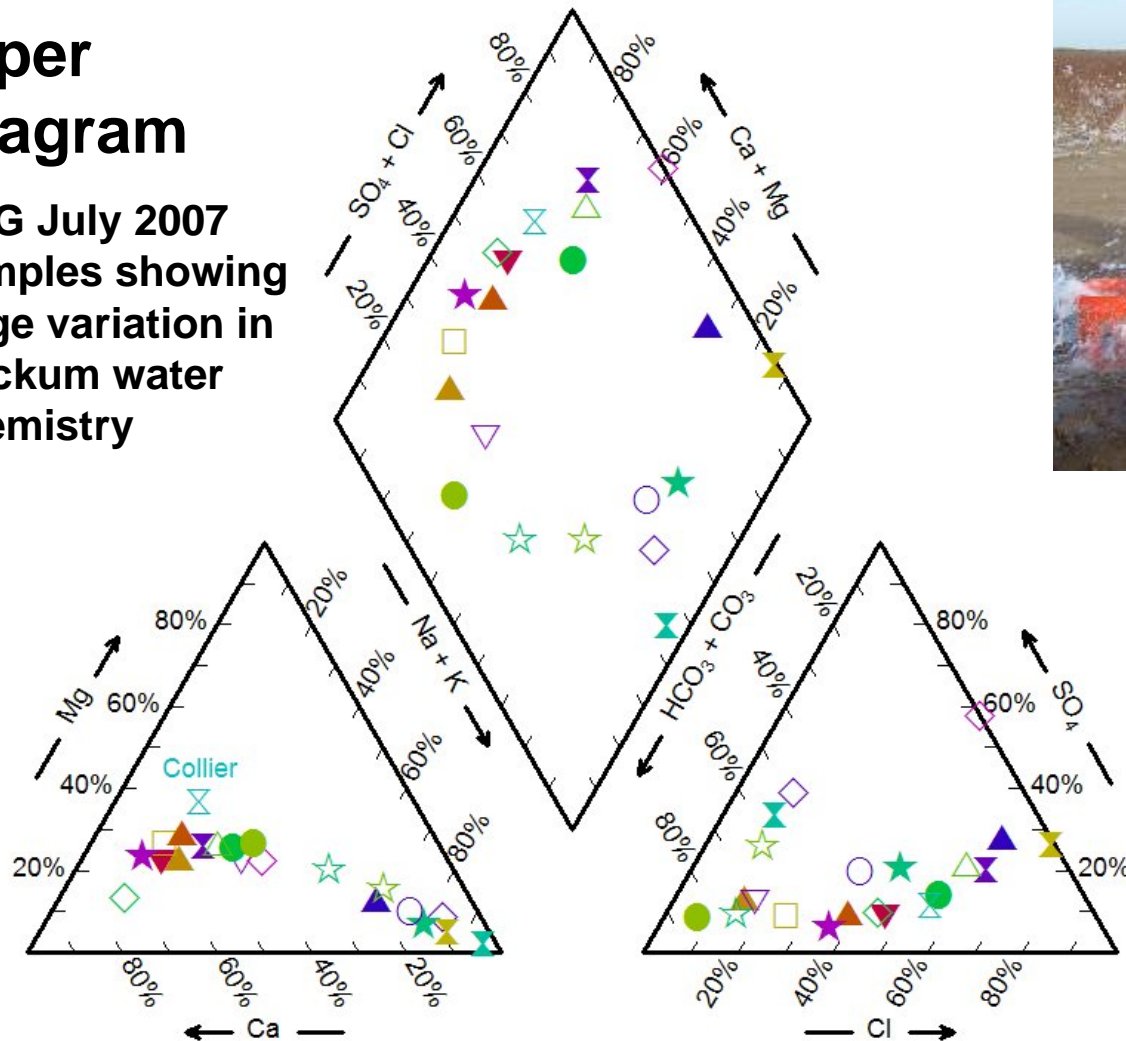
# SACROC Access to Private Water Wells



# Detecting Increased $\text{CO}_2$ in Groundwater

## Piper Diagram

BEG July 2007 samples showing large variation in Dockum water chemistry



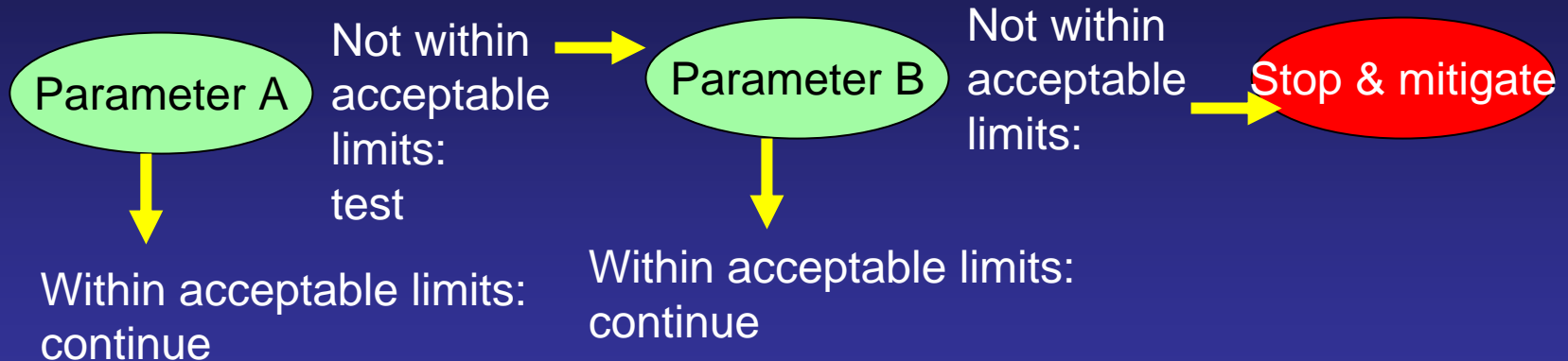
Need indirect measurement of  $\text{CO}_2$  in groundwater

↑  $\text{CO}_2$  = ↓ pH,  
↑ Alkalinity,  
↑ dissolved metals



# Need for Parsimonious Monitoring Program in a Mature Industry

- Standardized, dependable, durable instrumentation
  - reportable measurements
- Possibility above-background detection:
  - Follow-up testing program
  - assure public acceptance and safe operation
- Hierarchical approach:







# **GCCC Strategic Plan 2007-2010**

- **Goal 1: Educate next carbon management generation**
- **Goal 2: Develop commercial CO<sub>2</sub> site selection criteria**
- **Goal 3: Define adequate monitoring / verification strategy**
- **Goal 4: Evaluate potential risk and liability sources**
- **Goal 5: Evaluate Gulf Coast CO<sub>2</sub> EOR economic potential**
- **Goal 6: Develop Gulf Coast CCS market framework / economic models**
- **Goal 7: GCCC service and training to partners**

**[www.gulfcoastcarbon.org](http://www.gulfcoastcarbon.org)**